Principle of Hydraulic Machines and System Design
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Lecture – 27
Reaction Turbine: Francis Turbine

So, we will continue our discussion on Principle Hydraulic Machines and System Design. Today, we will discuss about reaction turbine; that is we have since we have discussed that the hydraulic turbine can be classified based you know based on the utilisation of head available. So, one is impulse turbine peloton wheel that we have discussed. Today, we will discuss about the you know radial flow reaction turbine that is Francis turbine and then we will discuss about the you know axial flow.

So, today we will discuss about the operational principle of a Francis turbine. And, then we will work out an example to see that, how we can you know based on the available head, how, we can get the total power and what should be the blade angle all those things? So, to do that let us first I will first draw a schematic of a reaction turbine and then we will discuss slowly about different features of the reaction turbine and how it is different from the impulse turbine?

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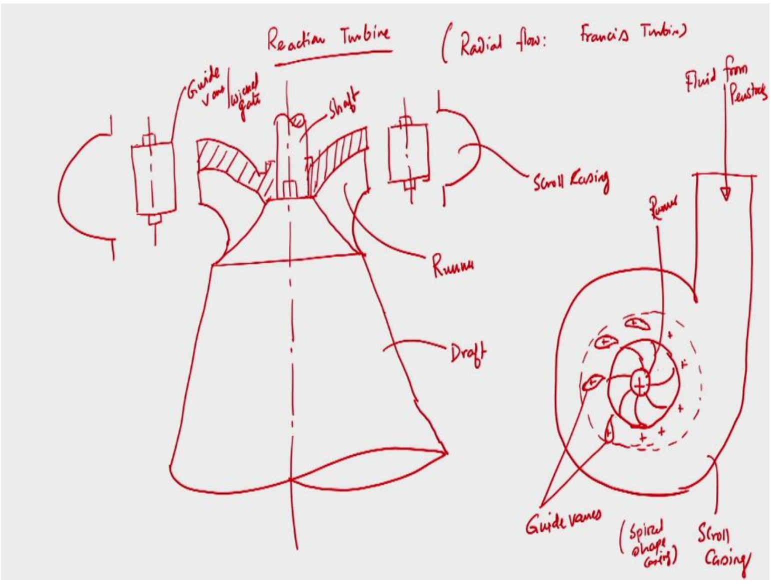

So, if I draw the schematic so, today we will discuss about reaction turbine. As, I said that the reaction turbine is different from impulse turbine, since in a reaction turbine pressure changes gradually you know as the you know fluid flows to the runner. So, whatever, what in case of a impulse turbine, we have seen that only one and two buckets are involve at a time to get the to in which conversion of the energy that is occurring.

But, in case of a reaction turbine this energy conversion takes energy conversion takes place gradually throughout the I mean entire portion of the runner. And, that is the basically you know fundamental difference between reaction and impulse turbine.

So, today we have taken example of a radial flow that is what I told you radial flow reaction turbine one example is the Francis turbine. So, if I draw the schematic first let me draw the schematic of a reaction turbines so, if I draw the schematic. So, this is the you know schematic of a radial flow reaction turbine is Francis turbine, this is I am now giving the I am just levelling different parts of it.

This is draft tube, this portion is the is runner, you know this is known as scroll casing this is shaft of the you know turbine and, these are known as guide vanes guide vane or sometime they are known as wicket gate. And, if I draw the another you know view here. So, this is the in cross sectional view so, this is draft tube, this is a runner shaft, we have scroll casing and then this draft tube is very important part of this is an integral part of the total hydroelectric power plant equipped with a radial flow or any reaction turbine.

But, this draft tube was not there in case of peloton wheel that you that is what you have seen. So, if I draw this schematic of a you know hydraulic turbine again, then we have a few wicket gates. So, we have a few wicket gates like this and then there will be a scroll case casing. So, this is scroll casing, this is schematic here fluid is coming from penstock, so, fluid is coming from penstock fluid from penstock you know these are called guide vanes.

And this is of course, runner this is runner. So, we have drawn the schematic of a you know reaction turbine we have given this cross sectional view as well as the schematic I mean the how it look likes, looks like then we have level different parts, we have a scroll casing shaft of course, shaft will be there. Another important component, which is integral with this turbine is draft you we will discuss one by one what is the function of that, then we have guide vane, we also will discuss what is the function of the guide vane and then scroll casing.

Now, as I said you that when we talk about reaction turbine, it differs from you know in impulse turbine. So, the principle distinguishing feature of a reaction turbine, how, it is differ from impulse turbine is that? In case of impulse turbine entire head available gross head rather head available at the inlet of a turbine is converted to the you know kinetic energy of rotation of the runner.

Before, it you know almost entire head is converted before it, you know goes to the turbine inside the turbine that is entire energy conversion taking place through a nozzle itself. Maybe one or two buckets at a times are engaged for this energy conversion through the nozzle.

Now, in case of reaction turbine only the part of the whole energy so, I am writing, how it is differing from impulse turbine? So, from the schematic again we need to look back the schematic, but how a reaction turbine is different from the impulse turbine?

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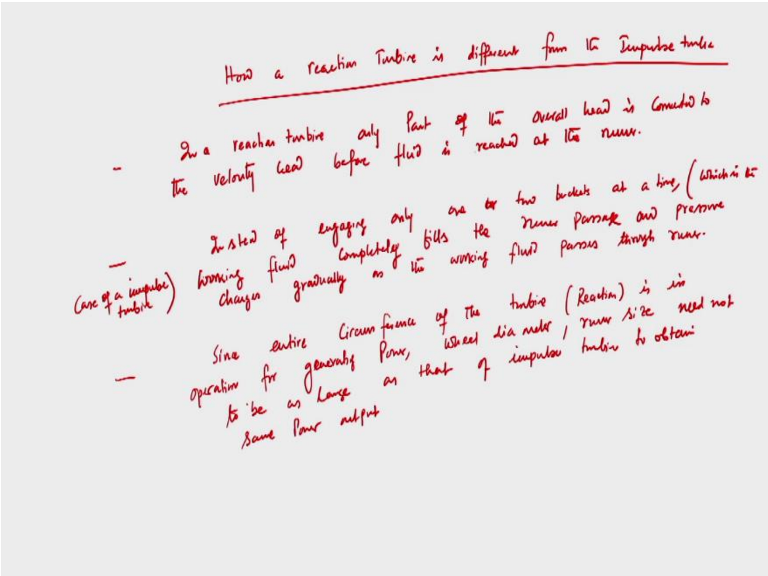

We will discuss one by one, so, I have said you that in a impulse turbine almost entire energy conversion takes place, before fluid goes to the runner. And, this energy conversion takes place through nozzle and at a time maybe one or two buckets are involved, but in case of a reaction turbine only a part of the energy conversion takes place, before the a I mean why? Because, pressure head is converted to the velocity head that the kinetic energy of the wheel that the runner.

Now, only part of the available head is converted to the velocity head before it goes to the runner. So, first of all in a reaction turbine, only part of the overall head is converted to the velocity head before fluid before the fluid is reached at the runner, at the runner.

So, before fluid reaching at the runner, only a part of the overall head that is pressure head is converted to the velocity head, but this is not the true for a impulse turbine. This is not the case for the impulse turbine, because almost entire part of the velocity a pressure head is converted to the velocity head through nozzle, and at a time may be one or two buckets are involved for this you know to obtain rather to increase the kinetic energy of the wheel.

Second is very important, that is what I am telling? That in case of impulse turbine at a time only one two buckets are engaged for this. So, instead of engaging only one or two buckets at a time, you know working fluid, which is the case of a impulse turbine, working fluid completely fills the runner, completely fills the passage entire passage completely fills the runner passage.

So, if I now go back to my previous slide it is clear that when water is coming from penstock, it is going through this scroll casing, it is sometimes, it is known as you know spiral shape casing, this is spiral shape casing. So, this is spiral shape casing a special name is scroll casing it is called. So, whenever water is coming from penstock, it goes through this spiral shape casing, but it is name is scroll casing. And, then the working fluid engaged almost all the blades entire runner at a time instead of engaging one or two buckets in case of impulse turbine.

That means, it is not the fact that only one or two bucket will be involve for this energy conversion and from there entire wheel will be rotating this is not the case rather, whenever water is or working fluid is coming from penstock, it will go through scroll casing, and it will completely fills the entire runner passage. And, while it is completely filling the entire runner passage, they are only the maximal energy conversion will take place, rather from overall head that is pressure head to the velocity head of kinetic velocity head and will have some kinetic energy of rotation of the runner.

So, this is another important difference and since it is a important, since the entire runner is you know engaged for this energy conversion in case of a reaction turbine, but while you have seen that only one or two buckets are involve for the energy conversion in case of impulse turbine. So, if you would like to obtain a same power output from a hydroelectric power plant, so, if the power plant is having a reaction turbine, then we require I mean you know lesser, I mean the wheel diameter, you know will be less, I mean wheel diameter and entire turbines size will be very less.

So, it is very important, that instead of engaging only one or two buckets at a time working fluid completely fills the runner, and pressure changes gradually as the working fluid, passes through runner right, this is important. Third is very important since the entire runner, entire circumference of the runner rather the reaction turbine is in operation, is in I mean operation for developing power or generating power.

Since, entire circumference of the turbine of course, reaction turbine you are talking about is in operation for generating power, wheel diameter wheel diameter you call it or runner size is need not to be as large as that of impulse turbine. Since, entire as I said you, since entire circumference is in operation; that means, the pressure changes gradually as it passes through the runner so; that means, all the runner passes, entire runner passes is in operation while this energy conversion taking place. That is why the rotor size runner size should not be as big as you know that of impulse turbine for generating to obtain same power output same power output.

This is very important so; that means, it is not the case like a impulse turbine because in impulse turbine only one or two buckets are involved at a time, and energy conversion taking place from nozzle and is striking the bucket. So, since only one or two buckets so, of course, to obtain the higher you know if you would like to obtain same power output from two different power plants; one is equipped with impulse turbine, another one is equipped with you know reaction turbine in.

So, of course, in case of a reaction turbine because of it is you know operational future we need not be you know, we need not to have a high wheel diameter or high rotor size, runner size, which is there and which should be the case for the impulse turbine.

So, this is economy I mean this is good, I mean that that the entire plant should not be as big as high in case of a impulse turbine. This is the fundamental difference between the reaction how a reaction turbine is different from impulse? So, these are the different characteristics feature of a reaction turbine and it makes it that it these features make this turbine to be different from impulse turbine, from construction point of view as well as the operational point of view.

Fine second thing we have discussed here that the water is coming from penstock and as water moves through the runner, I mean through casing spiral shape casing sometimes it is known as scroll casing. So, the casing is designed in such a way that, we have you have seen that in case of pump and water is coming out from pump and we have a casing.

Also, there is a spiral shape casing we have, but the area is gradually you know increasing. So, that the velocity head can be converted to a pressure head, before it goes to the discharge point, because entire purpose was in case of a pump is to develop a head. But, in case of a turbine whatever we are observing here that, that the scroll casing or the spiral shape casing is designed in such a way that, I mean the velocity will remain almost constant as it passes through the casing this is very important, that the fluid velocity must will remain constant into the casing so, this is another important feature.

Second thing this entire casing, which surrounds I mean the you know runner. So, I am writing here that what about the special feature of the spiral casing?

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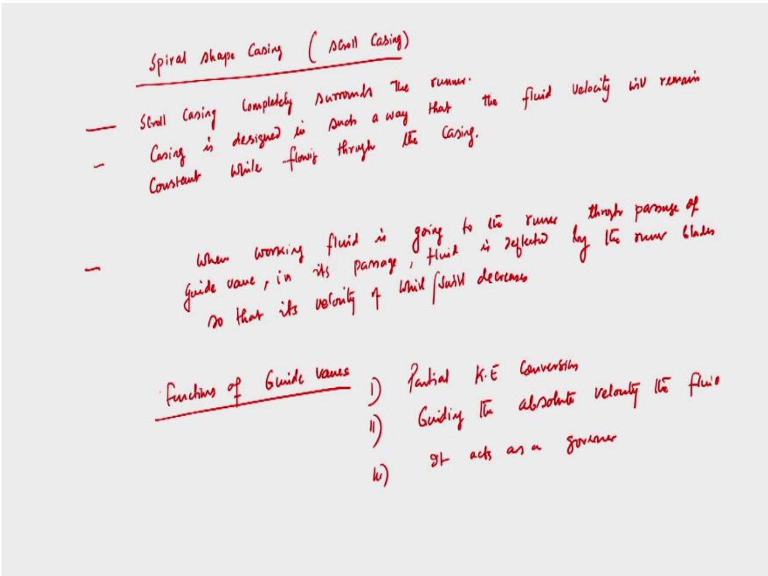

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So, spirals casing spiral shape casing which is known as also scroll casing, so, spiral shapes casing or scroll casings this is very important that, it should be designed in such a way the [piral/spiral] spiral shape casing or scroll casing should be designed in such a way, that the it will completely surrounds the runner. So, this casing completely surrounds the runner.

This scroll casing completely surrounds the runner, this is very important. And, the casing is design in such a way that the fluid velocity will remain constant, , while flowing through the casing.

So, these are the two important features; first one first one is the scroll casing completely surrounds the runner of course, we have seen from the schematic and casing should be design in such a way that that the velocity of the working fluid whatever is coming from penstock the velocity of that fluid is will remain almost constant while passing through the flowing through the casing. So, this is another important aspect for the casing shape. Now, if I go back to the schematic, so, what is happening? So, fluid is coming from penstock, it is now entering the casing and while it is moving to the casing velocity will remain almost constant.

Then what is happening? Very important that, when it is coming from penstock and moving to the casing then since it completely surrounds the casing completely surrounds the runner. So, it will try to go to the passes you know runner process through certain arrangement so, water will come from penstock, it will move through scroll casing where velocity will remain constant. Then, since the casing entirely surrounds the runner then water will go to the runner through certain arrangement or we are having wicket gates or guide vanes.

So, why you are having wicket gates or guide vanes, because each wicket gate or guide vane I mean these are placed around the periphery of the runner. The wicket gates and guide vanes are placed around the periphery of the runner and each of the wicket gates are pivoted each guide vane or you can get pivoted by suitable mechanism. And, it is possible that at a given time we can have since they are pivoted by suitable mechanism, either you can alter their you know they are opening at a time, at a given time, we can alter the opening of all the wicket gains all the wicket gates or if it is possible that we can alter the opening of a few or certain amount of a certain number of wicket gates this is possible.

So, we will discuss what is the function of wicket gates? So, before we go to discuss about this, first water will come from penstock it will move to the scroll casing, where velocity will remain constant, then water will go to the runner, and whenever it is going to the runner, it will pass through the wicket gates. Now, wicket gate or these guide vanes are pivoted by suitable, we can have you know all of them can be tuned at a time to alter the direction of quantity of water.

Note that, this you know this the you know the guide vane the function of guide vane is to drag the fluid, what is the function of the guide vane? The function of the guide vane is to direct the fluid to the up to an appropriate angle of the runner, I mean as per the designer choice. So, whenever water working fluid is coming from runner from scroll casing wicket gate will try to break the fluid to the runner at the angle to the designer choice.

So, now I just said you all the wicket gates are pivoted by suitable mechanism all of them can be tune at a time essential to alter the I mean direction of the quantity of water depending upon the load. So, maybe from a hydroelectric power plant will discuss maybe if time permits that, how we can controls speed governing mechanism? It is not always true that, we have to have always turbine will run at a same speed because you need to value the depending upon the low requirement.

Now, that is of a speed governing mechanism, but wicket gates can be tune at a time essential to alter the quantity of water that is going to the runner depending upon the low requirement. And, all the wicket gates are pivoted by suitable mechanism by virtue of which we can tune; I mean we can alter the opening. So, all of them can be of a tuned at a time or if it is require that we can find that we can operate only a few that is also possible. This moment of the guide vane how? Now question is question is how we can tune the movement of the guide vane either all of them or a few of them? By a that is that can be done by a speed governing mechanism of the turbine.

Now, question is whenever water is entering to the runner, I mean what whenever water is entering to the runner, that it passes runner whenever fluid or working fluid is entering to runner derivates passes through the runner, the runner blade the fluid is deflected because of the runner blades so, that it velocity of valve that is valve rates decreases.

So, I will write here now a few important things so, we have discussed that water will come through penstock, it will go to through the scroll casing, scroll casing is designed in such a way that the velocity will remain constant. Then water level go to go through the guide vane and it will enter to the runner, the function of guide vane is that the guide vanes were pivoted by suitable mechanism and the opening of the guide vane that the tuning of the guide vane is controlled by speed governing mechanism.

We can tune all the wicket gate at a at a given time or essentially to alter the direction of fluid flow depending upon the low requirement. And, second thing is whenever water is our working fluid is passing through the runner, they are you know that I mean working fluid will be deflected you know because of the guide vanes will be deflected, because of the runner blades or I mean either water or working fluid whatever it is, in it is passes through a runner fluid will be deflected because of the runner blade and so, that the velocity of valve it will decrease it is very important.

So, I am writing this is the overall situation, now when; working fluid is going to the runner from wicket gates through the passage of wicket gates, guide vanes when working fluid is going to the runner through the passage of guide vane, in it is passage, fluid is deflected because of the you know by the runner blades, deflected runner blades so, that it is velocity of runner blades, so, that heat it is velocity of swirl velocity of whirl or swirl decreases this is important so, velocity of solid decrease.

So, let us first now discuss about the working enough work you know function of the guide vanes. So as I said you that guide vanes are placed around the periphery of the you know runner of the turbine, guide vanes are pivoted by suitable mechanism and that all of them can be tuned at a time essentially to alter the direction of flow depending upon the requirement and they can be tuned by speed governing mechanism.

So, what are the function of guide vanes? So, if I write that function of guide vanes, what is the function of guide vanes it is very important or wicket gate. Essentially, you know partial kinetic energy conversion number 1 is not full, but partial kinetic energy conversion, that is partial velocity it will be converted to the velocity overall head would be convert into kinetic head and velocity head.

Number 2 guiding the absolute velocity of fluid guiding the absolute velocity of the fluid working fluid, guiding the absolute velocity of the fluid we can change the guiding angle. Number 3 it acts as a governor controlling the amount of fluid from penstock so, it as a governor I mean it control so, it acts as a governor; that means, by suitably tuning the guide vanes wicket gates, we can control the direction of fluid flow, we can control the amount of fluid that is entering. So, that it acts as a governor speed governor mechanism so, you can have depending upon the requirement of the load from that particular power plant we can change the you know how much quantity of water will go to the runner at a given time by opening the wicket gates. Also and it also as I said you that it also help in converting the partial amount of kinetic energy.

So, these are the function of you know wicket gates this is a very important function, it acts as a governor; that means, it is control the direction of fluid flow which can be done by speed governor mechanism that, we can tune the open it is opening.

So, that that amount of liquid as well as it is resistance can we controlled depending upon the load requirement. There is of course, a partial kinetic energy conversion within the bucket itself. And, of course, if guiding the absolute velocity of the fluid, as I said you that when fluid is coming from fluid is coming from guide vanes and it is entering to the runner, in it is passage fluid velocity is deflected by the runner blade so, that the velocity of the wall decreases.

So, I mean it is important that the guiding absolute velocity of fluid we can change the you know guiding angle. Since, it is absolute velocity if the fluid is guided by this so, we can change the guiding angle. Fine another, important part of that particular turbine is that, we will be having draft tube, what is the function of draft tube? So, when water is coming from runner I mean of course, from the centre of the runner all the fluid turn into the acceleration of the an face to the tendency level to the draft tube. So, from the centre of the runner so, when water is coming, from the centre of the runner fluid is turned into the axial direction, fluid is turned in to the axial direction. So, I am writing from the centre of the runner so, what is the function of draft tube? Very important this is import and another important part of this turbine.

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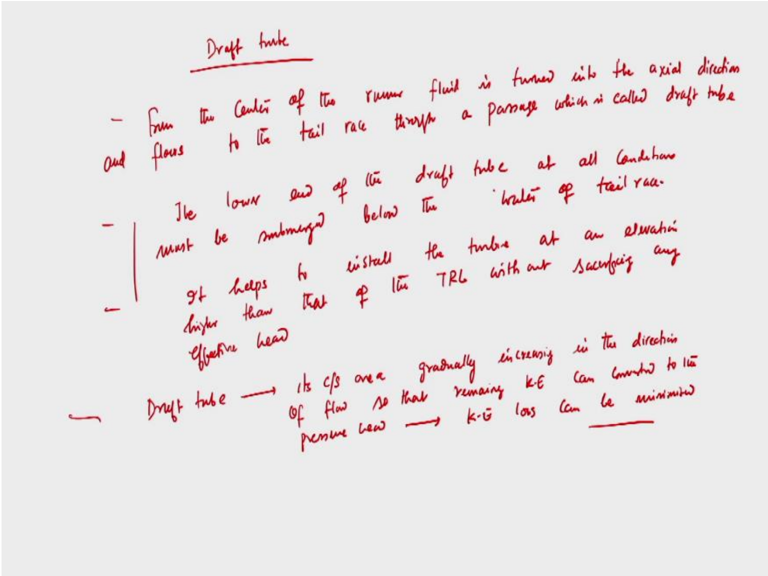

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So, what is the function of draft tube? Let me discuss about that draft tube shape is that it is gradually increasing in it is cross section area. So, whenever water is moving to the draft tube, we can have a recovery of the same amount of kinetic energy to the equivalent amount pressure head. Because, may be all the overall head is not converted in the turbine itself there will be some amount of kinetic energy, so, to gain that amount of kinetic energy instead of you know wasting this kinetic energy, we can have aft[er] certain arrangement so, that we can recover.

So, you know this is very importance so, as a function of the draft tube. So, when rather from the centre of the from the centre of the runner, fluid is turned into the axial direction into the axial direction and flows to tail race, so, the draft tube, flows to at tail race through a passage which is called draft tube.

So, from the centre of the runner fluid is turn into the axial direction and flows to the tail race level. And, whenever it is flows to the tail race level, then it flows through a particular flows to the tail race level, when a when it is going to the tail race level, it flows through particular shape of passage it is known as draft tube. So, and the lower end of the draft tube must under all condition operation will be some other tail race level.

This is very important, that the lower end of the draft tube at all working condition at all condition must be submerged below the tail water level must be submerged below the tail water, you know tail water below the water below the water level in the below the water in the tail race, tail water tail below the water of tail race.

So, this is very important, that you know what is function of the draft tube, that is the important this special arrangement. You know that lower end of the draft tube at all working condition must be submerged below the water have a tail race level.

Since and as I said you the cross section of the draft tube is gradually increasing in the direction flow to minimise the kinetic energy loss at the turbine. So, since the lower end of the draft tube at all working condition must be submerged below the water as level, it goes to install a turbine and higher than that of the tell race without losing you know losing it any (Refer Time: 36:29). So, because of this, it helps to install the turbine at an elevation higher than the TRL at an elevation higher than the Tell Race Level higher than the TRL.

So, that higher than that of sorry higher than that of the TRL, it helps to install the turbine, at an elevation higher than that of the TRL; tail race level without losing, without sacrificing any working head, without sacrificing any effective head. That means, without sacrificing effective we can install turbine at elevation, which is higher than the TRL because, that is that is only possible because of the draft tube. So, the draft tube what is the function from the centre of the turner fluid is turn into the excel direction and flows to the TRL level through a passage, which is known as draft tube the lower end of the draft tube.

The, lower end of draft tube that all working condition must be submerged in the TRL level and since we are having draft tube so, it is always possible that we can install turbine at the elevation, which is higher than the water level in that TRL, without sacrificing effect head. Now, the draft tube as I said you it is cross sectional area gradually increasing in the direction of flow.

So, that as I said you that may be all the overall head is not converted into the kinetic head. So, some remaining amount of pressure head is still here so, you can still utilize, convert that into the gradually increasing area. So, reducing the velocity so, to minimise and not to so, maybe all the you know the head converted to the pressure head to the kinetic head maybe it is not used to obtain equivalent amount of power.

So, whatever amount of kinetic head that you are having at the end of the turbine, we can we can regain that kinetic energy into the equivalent amount of pressure head, but I do not know equivalent amount of pressure head or not but still some un utilised kinetic energy can be again recovered whenever fluid is flowing through the draft tube because of it is shape.

So, the cross section area is gradually increasing; that means, in the direction of flow so, that the unutilized or the remaining kinetic energy in it can be converted to the pressure head, whether equivalent by an equivalent amount or not that is not that is very difficult to say, but still that so, that the you know remaining kinetic energy can be converted; remaining kinetic energy can be you know converted to the pressure head. That means; kinetic energy loss can be minimised.

So, this is all about the reaction turbine that, how we can have a different so, we have discussed different plots operational principal of a reaction turbine, how it is different from the impulse turbine? And, there are few parts which are integral to this turbine and we have discussed about their function. Draft tube is very most important part, because of the draft tube we can install turbine at a elevation level, which is higher than the water level of the TRL. Not only that draft tube helps in recovering the remaining kinetic energy to the pressure head so, that the efficiency can be increased not only that the kinetic head loss can be minimised.

So, with this you know background, we now next to move to solve one problem based on this reaction turbine. So, we will solve one a problem on reaction turbine and we will write the problem first.

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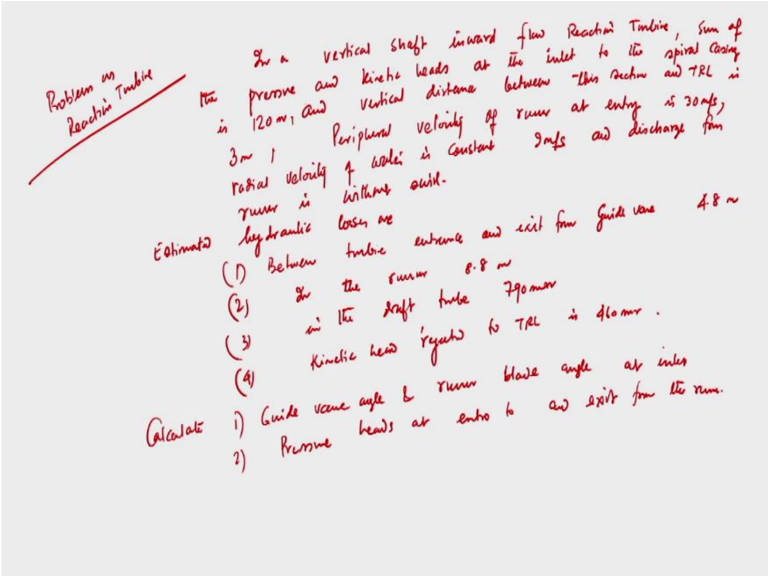

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Problem on reaction turbine, in a vertical shaft in ward flow reaction turbine so, in a vertical shaft inward flow reaction turbine the vertical flow reaction turbine so, sum of the pressure head kinetic heads at the intensive parallel spacing is 120 meter, sum of the pressure and kinetic head pressure and kinetic heads at the entrance at the inlet of the spiral casing, at the inlet to the spiral casing is 120 meter. And, vertical distance between this section and TRL and vertical distance between this section and TRL; TRL level is 3 meter right, peripheral velocity of runner at entry, the peripheral velocity, the peripheral velocity of runner at entry is 30 meter per second, the radial velocity of water is constant and that is 9 meter per second, discharge from the runner without and discharge from the runner is without solved.

Fine the estimated hydraulic losses are so, estimated hydraulic losses are very important between turbine entrance and exit from the guide vanes 1, between turbine entrance and exit from guide vane is 4.8 meter.

Number 2 this is 4.8-meter, number 2 the runner in the runner it is 8.8-meter hydraulic losses, number 3, in the draft tube 790 meter, in the draft tube because fictional is hydraulic losses we cannot ignore. In the draft tube it is 790 millimetre, number 4 very important kinetic head ejected to tell less, still even they were having draft tube, but still some amount of kinetic energy remaining we cannot recover all this, that is why I told that whether I do not know you can convert equivalent amount of pressure or not, that is that is not possible at all.

So, kinetic head rejected to TRL is 460-meter millimetre 460 millimetre this is 790 millimetres. So, we have to calculate very important the guide vane angle at the and the runner blade angle at the inlet. So, we have to calculate this is very important guide vane angle and runner blade angle at inlet and pressure head at entry and entry to and exit from the runner, 1 2 pressure head, pressure heads at entry to and exit from the runner.

So have this is the problem we have to solve this problem. So, this is the problem, but we need to solve how can you solve that we will that you need to solve again we will solve it, it is not very difficult problem at all because you know everything. So, how we can solve? This very important, because it is given that in a verticals of inner flow reaction turbine some of the pressure and kinetic heads at the inlet of the spiral casing 120 meters and the vertical distance at the section TRL and TRL between the between the section and TRL is 3 meter, peripheral velocity of the runner at the entry is 30 meter per second radial velocity of water is constant 9 meter per second, discharge from runner is without solve.

We have to calculate, hydraulic velocity is given between turbine entrance and exit from the guide vanes runner it is given, draft to is given, kinetic energy rejected or total is given, you have to calculate the guide vane angle and runner blade angle at the inlet pressure head at entry run to exit from the runner. So, we have to solve this problem.

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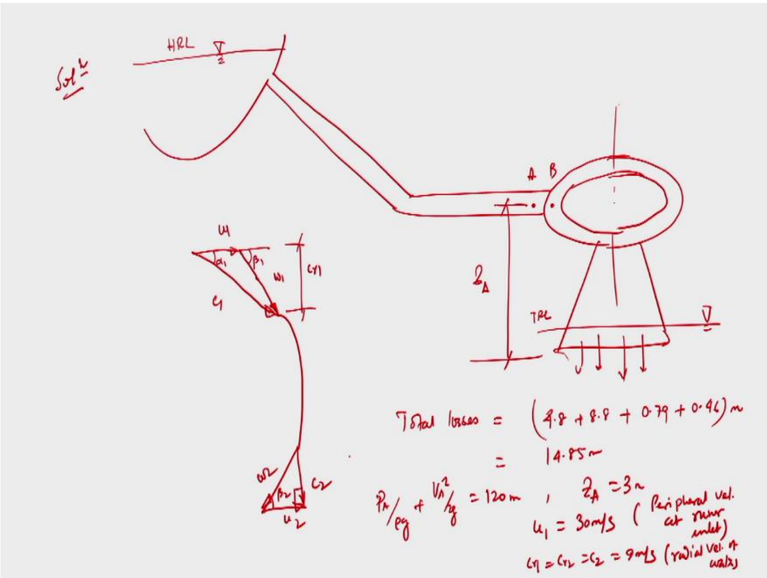

So, we now we will solve solution very important so, if draw the schematic suppose this is the so, this is head ratio level, it is coming from penstock and this is turbine. So, we are having let us say this is the turbine. So, we have draft tube so, from where water is discharging.

And, this is as I said will draft to will always seductive somewhere below the TRL so, this is TRL. And so, this is let us say this point is A and this point is B this is A so, this distance is z A right. So, if you draw the velocity triangles how to how we can obtain? Velocity triangles, we can obtain inlet velocity triangles so, this is u 1 this is w 1 and this will be c 1; w 1 this angle is beta1 this angle is alpha 1 this is u 1 this is c 1.

So, now, this is outlet velocity triangle w 2 that is no swirl it is given so, this is c 2, this is beta 2, this is w 2, and this is u 2. It is given that no swirl so, if I go back to my previous slide, it is given that it discharges from runner without swirl so, it is 90 degree. So, how we can solve this problem? So, total losses total hydraulic losses are equal to how much, it is given 4.8 plus 8.8 plus 0.79 plus 0.46 meter, that is equal to 14.85 meter is a total losses.

$$\frac{P_A}{\rho g} + \frac{{V_A}^2}{2g} = 120$$

that is that is what is very important at the some of the pressure and kinetic energy inlet to the spiral casing. So, A is the inlet to the spiral casing the point A is the inlet to the spiral casing.

Za = 3m

Cr1 = C2 =9m

So, what you have to calculate, we have to calculate beta 1 and beta 2 that we have given. So, we need to calculate something that you already, we know that I have to calculate guide vane angle and runner blade angle at the inlet pressure heads at entry and exit from the runner.

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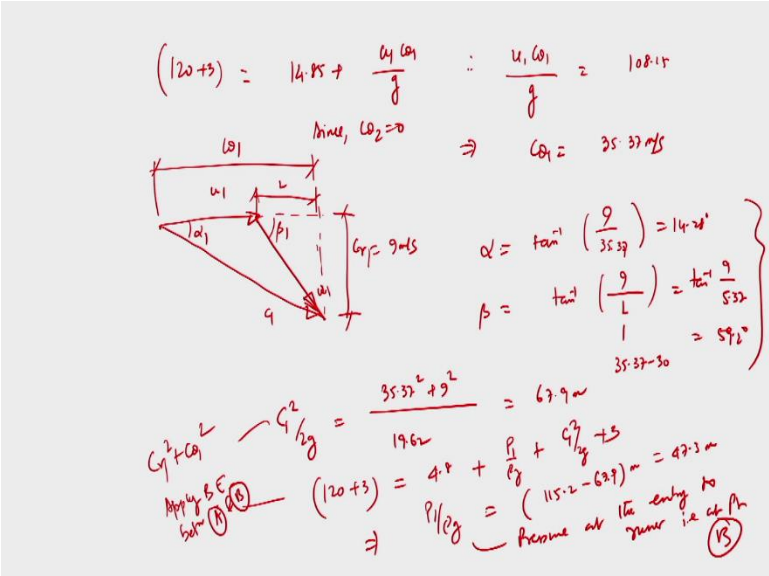

$120+3 = 14.85 + \frac{u_1 C_{\theta 1}}{g}$

$\frac{u_1 C_{\theta 1}}{g} = 108.15$

$C_{\theta 1} = 35.37\ m/s$

$C_{\theta 2} = 0$

$\alpha = tan^{-1}\left(\frac{9}{35.37}\right) = 14.28$

$\beta = tan^{-1}\left(\frac{9}{5.37}\right) = 59.2$

$\frac{{C_1}^2}{2g} = \frac{35.37^2+9^2}{19.62} = 67.9\ m$

$120+3 = 4.8 + \frac{P_1}{\rho g} + \frac{{C_1}^2}{2g} + 3$

$\frac{P_1}{\rho g} = 47.3m$

$\frac{P_2}{\rho g} + \frac{{C_2}^2}{2g} + 3 = 0.46 + 0.79$

$\frac{P_2}{\rho g} = -5.8\ m$

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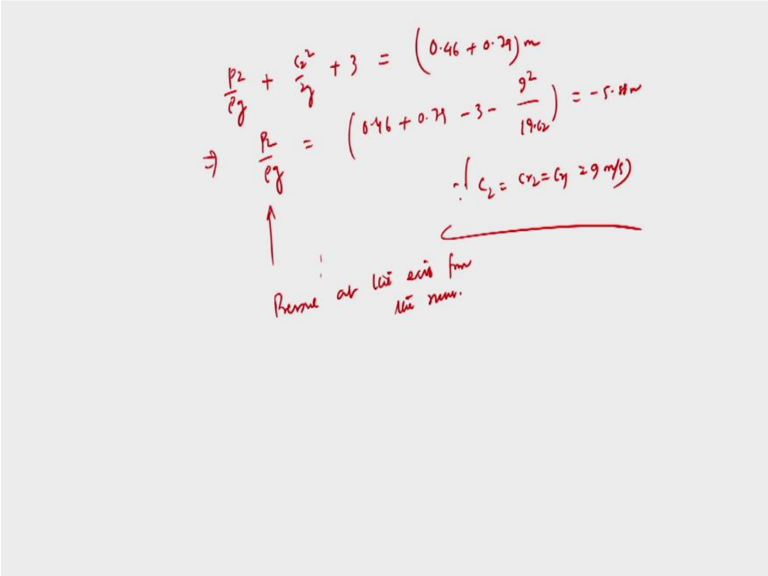

So, we have obtain everything, so, we have obtain that you know pressure which is you know available, that is what that angle measure pressure head at the entry and exit from the runner. Entry, of the runner at the point B so, this is pressure at the entry to the runner, that is at point B.

Similarly, at exit of the runner that is P_2 exit of the runner is this point this one let us c and that is pressure at the exit from runner. So, we have obtained all the answer so, we have to solve the problem in the in this way. So, with this I stop here today, and we will continue our discussion in the next class.

Thank you.